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Distribution and abundance of *Hydrastis canadensis* L. (Ranunculaceae) and *Panax quinquefolius* L. (Araliaceae) in the central Appalachian region[1]

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McGraw, J. B., S. M. Sanders, and M. E. Van der Voort. (Department of Biology, West Virginia University, Morgantown, WV 26506-6057). Distribution and abundance of *Hydrastis canadensis* L. (Ranunculaceae) and *Panax quinquefolius* L. (Araliaceae) in the central Appalachian region. J. Torrey Bot. Soc. 130: 62–69. 2003.—As demand for goldenseal (*Hydrastis canadensis* L.) and ginseng (*Panax quinquefolius* L.) intensifies due to the herbal plant trade, basic information about distribution and abundance is needed to inform management strategies. We surveyed 16 sites focusing on West Virginia, but including nearby sites in Pennsylvania, Kentucky, Ohio, and Maryland to determine *H. canadensis* and *P. quinquefolius* presence and abundance. In total we surveyed 29.32 ha over two summers in a wide range of aspects, elevations, management regimes and forest cover types. So few patches of goldenseal were encountered that we were unable to detect statistically significant effects of elevation, aspect, land use or vegetation on either encounter probability or density. Ginseng was more frequently encountered than goldenseal. The probability of encountering ginseng increased with elevation. Overall, ginseng was not more frequent or abundant on north-facing 'cove' forests. A significant elevation x aspect interaction was found, whereby ginseng was most abundant on west-facing slopes at low elevation, but more abundant on east-facing slopes at middle elevations. Extrapolations of ginseng densities to the state of West Virginia suggest that the species is not rare in the typical sense. Instead, it is widespread, but scarce everywhere it is found. Harvest rates are estimated to be ca. 5% of the natural ginseng population annually. Understanding basic ecological relationships and management of these species is made difficult by the widespread, dispersed nature of individuals, patches and populations and the complex interaction with human harvesters.

Key words: *Panax quinquefolius*, ginseng, *Hydrastis canadensis*, goldenseal, rare plant distribution, central Appalachian, wild harvested plants, herbal plants.

Ginseng (*Panax quinquefolius* L.) and goldenseal (*Hydrastis canadensis* L.) are herbaceous perennial plants of the eastern deciduous forest, and are actively sought and harvested from the wild. They are sold on the herbal market where *P. quinquefolius* has commanded from $330/kg to $1,100/kg in recent years (Robbins 1998; 2000; Bailey 1999). The price of *H. canadensis* was $66.00/kg in 1998 (Bailey 1999). This demand provides a significant incentive for harvesters to dig plants from the wild, particularly in areas where unemployment is high (Bailey 1999). Although few sources document historic population levels (Davis 1976; Eichenberger and Parker 1976; Carlson 1986; Anderson et al. 1993), there is general agreement among biologists, natural resource managers and harvesters that abundance of these species is declining (Charron and Gagnon 1991; Catling and Small 1994; Sinclair and Catling 2000a). Both species are currently listed on Appendix II of the CITES treaty (Convention on International Trade in Endangered Species of Flora and Fauna). Therefore, the species must be monitored, and the federal government must certify that their harvest remains "non-detrimental" to permit international trade (Robbins 2000).

Little is known about the distribution and abundance of wild harvested plant species within their ranges (Anderson et al. 1993; Sanders and McGraw, 2002). Characterization of the environment where known populations occur can partially describe a species' niche (Anderson et al. 1993). With stratified random sampling, however, one can define the boundaries of the niche by learning where the species is absent, as well as where it is present.

The objectives of this study were twofold. First, we wanted to determine the mesotopographic distribution patterns of *H. canadensis* and *P. quinquefolius* near the center of their ranges. Specifically, we examined their presence and abundance among sites varying in aspect and elevation. Obviously, the present distribution and

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abundance may represent a shift from historical, preharvest distributions. Nevertheless, an understanding of the current distribution and abundance of these two species should clarify their realized niche breadth and thereby aid in their management as non-timber forest resources. Our second objective was to estimate roughly the density of *P. quinquefolius* across a representative area in the central part of its range (the state of West Virginia). Using this information, along with estimates of harvest over the past several years, we estimated the harvest pressure on wild ginseng populations. The rate of harvest is a key statistic for understanding impacts and sustainability of harvesting that was heretofore unknown.

Materials and Methods. *P. quinquefolius* is found throughout the eastern United States with the exception of the extreme south and southeast. Its range extends westward to the states forming the western border of the Mississippi River and north into Canada, in Ontario and Quebec. Close relatives include *P. trifolius* L. (dwarf ginseng) which also grows in eastern North America and *P. ginseng* C. A. Meyer (Asian ginseng), native to Asia. *P. quinquefolius* emerges each year from an underground rhizome in May. Flower buds are evident in mature plants after full expansion, flowering occurs in June, and berries ripen in August and September. The ginseng root is used in traditional Chinese cooking and medicine. In part because the root sometimes resembles a human form, it is believed by users to have therapeutic powers. Since this plant does not have any means of asexual propagation, harvest of an individual kills the plant.

H. canadensis is found from New York west through southern Michigan and south through Missouri and Tennessee; this range includes southern Ontario in Canada. *H. canadensis* has historically been most abundant in Ohio, Indiana, West Virginia, and Kentucky (Sinclair and Catling 1998). Mature *H. canadensis* emerge with a flower bud from an underground rhizome in early April. The flower is apetalous with deciduous sepals. Flowering occurs in mid to late April and berries ripen by July. Goldenseal spreads clonally to form patches of tens to thousands of loosely connected ramets. Although a thorough harvest could kill a single genetic individual, more often some ramets remain in the soil, providing a means of recovery (Van der Voort et al. 2003).

SURVEY METHOD. A random survey for a rare plant species presents severe challenges because of the low encounter rate across the landscape. In this study, our survey method evolved through three stages to become more efficient at detection. However, to maximize our return on effort expended at each stage, we include data derived from all three methods. For analyses of the effect of elevation and aspect on encounter probability, each dataset was examined independently since encounter probabilities would vary as a function of area of the sampling unit. However, for density studies, a meta-analysis was performed including all three data sets, with observations weighted appropriately by the area of the sampling unit.

Stage 1: At this stage (summer, 1995), we employed a traditional stratified random sampling method to assess presence and abundance of ginseng and goldenseal in the Otter Creek Wilderness Area in the Monongahela National Forest (Van der Voort 1998). In three watersheds, random sites were selected within each of the four main aspects, at a range of elevations within each aspect. Seventy-one 4 m $\times$ 50 m transects were carefully surveyed and marked with flagging, then censused (a total area of 14,200 m^2 were censused with this method).

Stage 2: In order to increase the area sampled, in summer 1999 we increased plot size to 25 m $\times$ 150 m, with each plot divided into separately-censused 25 m $\times$ 25 m subplots. Subplot corners were marked with flagging and distances determined with a tape measure. This method was used for four transects at each of three sites: Forks-of-Cheat Forest, Zimmerman Tract, and Chestnut Ridge (a total area of 45,000 m^2).

Stage 3: The process of surveying precise distances over steep terrain took large amounts of time, which limited the area that could be censused. Therefore, after completing surveys of three sites with the stage 2 method described above, in summer, 1999 we devised a moving-transect approach in which we simultaneously set up the transect and censused as we traversed each site. The long dimension of each transect (400 m) was determined with a digital measuring wheel (DigiRoller Plus, Calculated Industries). The width of the transect (15 m) was determined with an electronic distance measurer (SoninPro, Sonin, Inc.) every 50 m along the transect. With this method, the width of the area surveyed was not as precisely outlined as with our methods of stage 1 or 2, however checks on the width showed that deviations from 15 m tar-

Table 1. Survey sites and locations censused.

Site name (abbreviation)	Location
West Virginia University Core Arboretum (CA)	Morgantown, WV
Big Run State Park (BR)	Grantsville, MD
Cabwaylingo State Park (CB)	Dunlow, WV
Camp Creek State Park (CC)	Camp Creek, WV
Chestnut Ridge (West Virginia University Forest) (CR)	Morgantown, WV
Daniel Boone National Forest (DB)	Winchester, KY
Forks-of-Cheat Nature Preserve (FC)	Morgantown, WV
Holly River State Park (HR)	Hacker Valley, WV
Meadow Bridge private residence (MB)	Meadow Bridge, WV
North Bend State Park (NB)	Cairo, WV
Ohiopyle State Park (OP)	Ohiopyle, PA
Otter Creek Wilderness (3 Sites)	Parsons, WV
Wayne National Forest (WN)	Athens, OH
Zimmerman Tract (ZM)	Morgantown, WV

get width were generally < 1m and they varied both above and below the target. Therefore, the error in transect area measurement was < 10%. Between transect edges, trained observers 2–3 m apart moved in tandem along the transect at a pace that allowed them to thoroughly search for plants. We were able to cover more than twice as much area per unit time with this technique. Therefore, we were willing to sacrifice some precision in area measurement for the gain in sample area, thus reducing the chance of Type II statistical error. A total of ten sites were surveyed in this manner, most sites with four 15 m × 400 m transects, located on a range of aspects (Table 1; total of 234,000 m^2 surveyed by this method).

In stage 3, we estimated percent tree species canopy coverage in a 15 m × 25 m section of the center of each 15 m × 50 m subplot in the transect. If more than 35% of the tree canopy was one species, the community was characterized as dominated by that species. If the most dominant species comprised < 35% of the canopy, the community was designated as 'mixed'. On two occasions, two species each comprised 40% of the canopy, so these two communities were designated 'mixed'. By this process 12 forest community types were encountered in the subplots. However, since 8 of these were represented by fewer than five subplots, only four community types were included in the analysis: (1) *Quercus rubra*—*Quercus alba* type, (2) *Liriodendron tulipifera* type, (3) *Acer saccharum* type, and (4) Mixed type. Since the forest community varied widely along a transect, the subplot was considered the appropriate sampling unit when examining ginseng and goldenseal presence/absence or density as a function of forest overstory.

Using all methods, the field crew of 4–6 persons carefully surveyed 29.32 ha at 16 sites representing a wide range of elevations, aspects, site histories, land use designations, management regimes and forest types over two summers. While these sites cannot be considered a truly random representation of the forested potential sites for locating ginseng and goldenseal, the diversity of sites allows a first approximation of the density of these plants in the field as well as a determination of some factors influencing their presence and abundance. Mean overall density was calculated by weighting each observation by the sampled area. For the state of West Virginia, we estimated total ginseng population size by multiplying the forested area of the state (DiGiovanni 1990) by the estimated density of ginseng plants based on our survey. Percent of plants harvested annually was estimated by determining the mean state total harvest weight of ginseng plants from 18 years of data during the period of 1978–1999 (U. S. Fish and Wildlife Service, personal communication 2000), and calculating number of plants harvested by using the approximate number of roots per unit dry weight of sold ginseng. The focus on West Virginia for this part of the study was because harvest data are reported on a state by state basis.

STATISTICAL ANALYSIS. The effect of elevation on species presence in a transect was examined with logistic regression, separately for stage 1 and stage 3 survey methods (n was too small to do this for stage 2). Aspect at each site was classified as north (315°–45°), east (46°–135°), south (136°–225°), or west (226°–315°). The effect of aspect on presence of a species in the transect was then examined with a G-test, again, separately for stage 1 and stage 3 data.

The effect of forest cover type on presence of each species was also examined with a likelihood ratio test (*G*-test).

To examine density variation, two-way analysis of variance was performed on plant numbers per unit area within transects with aspect and elevation as main effects in the model. Normality was improved by log transforming the original data. Each observation was weighted by the area of the transect, thus appropriately giving more weight to transects having a larger area. Aspect was measured on each subplot within a transect and subplots with an aspect differing from the majority in the transect were deleted to ensure that the entire transect had only one aspect. Because we suspected that aspect effects might depend on elevation in a nonlinear fashion, we formed discrete elevation classes for this analysis. Elevations of less than 400 m were termed 'low' elevation transects, 400–700 m were 'mid' elevation transects, and >700 m were 'high' elevation transects.

Ginseng density was also studied as a function of land ownership (public vs. private). A nested ANOVA was used to test for density differences, with site nested within ownership class. Density was also related to forest cover type using one-way ANOVA. In all tests, normality of residuals was tested using the Shapiro-Wilk W test. Where necessary, data were transformed with natural logarithms to improve normality.

Results. In the entire sampled area, we encountered 539 ginseng plants (=genets) and 1,257 goldenseal ramets. The weighted mean density of ginseng was 18.26 individuals per hectare and the density of goldenseal ramets was 42.58 per hectare. The number of genetically-distinct individuals of goldenseal was unknown since extensive clonal growth precluded determination of genet number. However, given the size of patches believed to be single genets (5 to >1,000 individuals; McGraw, Sanders and Van der Voort, personal observation, 2001), genet density is likely to be between 1 and 3 orders of magnitude less than ramet density; therefore goldenseal genets were more rare than ginseng plants. Sites differed significantly in terms of the presence of ginseng ($G = 21.1$, $P = 0.012$, df = 9), however goldenseal was so infrequently encountered that no significant difference among sites was found for this species ($G = 11.25$, $P = 0.259$, df = 9).

Ginseng was more spatially dispersed than goldenseal. There was a tendency for ginseng to be encountered at sites more often than goldenseal; 7 of 10 sites (70%) for ginseng vs. 3 of 10 (27%) for goldenseal in the stage 3 analysis ($G = 3.291$, $P = 0.070$, df = 1; Sokal and Rohlf 1995). This pattern was supported by transect data as well. For example, in the 15 × 400 m transects, ginseng was found in 13 of 39 transects, while goldenseal was found in only 4 of 39 transects.

To put these numbers in perspective, we extrapolated that if this density were representative of the forested area of West Virginia, then the state would contain approximately 87.8 million ginseng plants. Annually, harvesters have sold an 18-year mean of 8359 kg / y of dried ginseng root in the state (Office of Scientific Authority, U. S. Fish and Wildlife Service, personal communication, 2000). A recent estimate of average root size (1.94 g per root; Whipkey, West Virginia Division of Natural Resources, personal communication 2001) suggests that this harvest represents ca. 4.3 million plants. Therefore, the estimated harvest rate is 4.9%. Of course this percentage is estimated with error. However, due to the limited sampling of the land area, the unknown variance in individual root weight, and the likely error in reporting of total harvest, it is impossible to compute confidence limits on this number. We therefore claim only that the harvest rate of 4.9% is a first approximation based on the best available data.

For the Otter Creek Wilderness dataset (stage 1: 4 × 50 m quadrats), no goldenseal was found in any of the quadrats. Ginseng was present in 8 of 71 transects, but its presence was explained by neither elevation (logistic regression, $P > 0.05$, df = 1) nor aspect (*G*-test, $P > 0.05$, df = 3). For the Stage 3 sampling (15 × 400 m transects), a significant increase in presence of ginseng was found with increasing elevation (logistic regression, $P = 0.012$), while no such elevation effect was detected for goldenseal (logistic regression, $P > 0.05$, df = 1, Fig. 1). The incidence of ginseng was greater on east and west aspects than on north and south aspects ($G = 15.120$, $P = 0.002$, df = 3), while the incidence of goldenseal did not vary significantly with aspect (Fig. 2; $P > 0.05$, df = 3).

Abundance of ginseng, as measured by plant density, did not vary significantly with either aspect class or elevation class alone (2-way ANOVA main effects, $P > 0.05$, df = 2 for elevation class, df = 3 for aspect class). However, the effect of aspect class depended on elevation

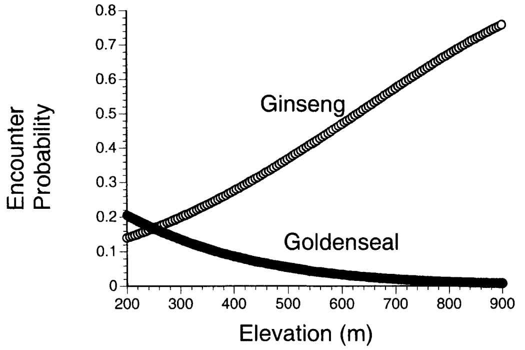

Fig. 1. Probabilities of encountering ginseng, and goldenseal as a function of elevation for the stage 3 data set as determined by logistic regression.

class (2-way interaction; $F = 2.443$, $P = 0.030$, numerator df = 6, denominator df = 110), with west-facing slopes showing greatest abundance at low elevation and east-facing slopes having greatest abundance at mid-elevations (Fig. 3). High elevations generally had lower ginseng densities on all aspects. Due to the rarity of goldenseal among our transects, analysis of abundance variation was not possible.

There was a ca. five-fold greater mean ginseng density on the three private properties surveyed (14.7 plants ha^{-1}) than on the remaining public lands (2.6 plants ha^{-1}, nested ANOVA, $F = 5.444$, $P = 0.037$, numerator df = 1, denominator df = 12). In addition, among sites within ownership categories, there was significant variation in ginseng density ($F = 6.311$, $P < 0.0001$; numerator df = 12, denominator df = 108). No difference in ginseng presence (*G*-test) or density (ANOVA) was found in subplots with differing canopy tree cover types ($P > 0.05$).

Discussion. Ginseng and goldenseal have a somewhat unusual form of rarity in that they have a broad distribution, can occur in a variety of forest community types, aspects and elevations, and yet they are not abundant anywhere (Rabinowitz 1981). This distribution severely challenged the classical stratified random transect survey approach we employed to characterize distribution and abundance of the two species. Indeed, we can conclude that the method failed completely in characterizing goldenseal habitat preferences since so few transects contained goldenseal regardless of transect size. Despite extensive, time-consuming sampling with a large field crew, no significant effects of elevation, aspect, site, or forest cover were found for presence of goldenseal. Indeed, the frequency of zeros in the data set made analysis of abundance virtually impossible (no transformation could rectify the non-normal distribution). It seems highly likely that this is not because no such relationships exist, but instead because our detection frequency and resultant sample size (and therefore statistical power) was too low to reveal trends or significant differences. Unless goldenseal is an extreme generalist (which seems highly unlikely), we conclude that by sampling in this manner we committed a form of Type II statistical error. Therefore, it is important to emphasize that goldenseal may well have specific environmental requirements, but that a different approach will be required to elucidate them. Indeed, Sinclair and Catlin (2000b) as well as our own previous work (Sanders and McGraw 2002) suggests that goldenseal responds to local disturbance gradients. Light gaps and soil disturbance appear to stimulate local patch proliferation. Disturbance history was unknown for most of the sites examined in the present study, therefore this aspect of goldenseal ecology was not considered here.

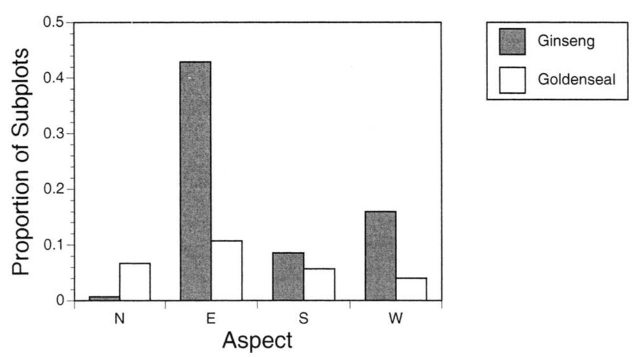

Fig. 2. Proportion of subplots containing ginseng or goldenseal in differing aspect classes for the stage 3 data set.

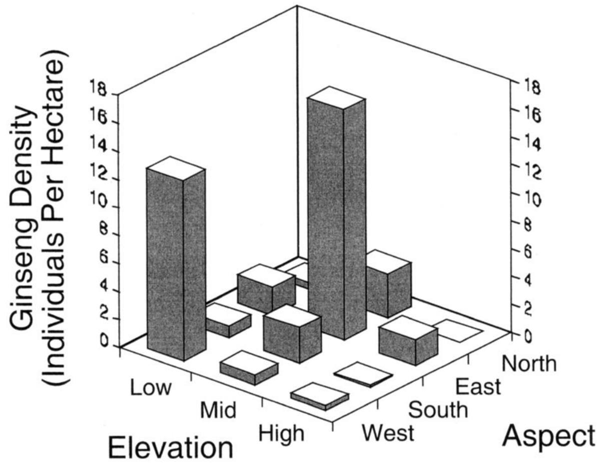

Fig. 3. Least squares means of ginseng density as a function of aspect class, and elevation class in the pooled data set.

A simple, yet potentially flawed alternative to the classical approach is to identify known goldenseal populations and characterize the environment there. This description then defines the niche of the species. This approach has been used to characterize the environments of known ginseng populations in Illinois (Anderson et al. 1993) and in Arkansas (Fountain 1986). Their conclusion that most ginseng populations in Illinois and Arkansas are found on north- or east-facing slopes under particular sorts of tree canopies relies on the sample being a random sample of populations. However, in these studies, as in most studies of rare plants, the painstaking process of finding populations through random sampling was not followed. Therefore, botanists' preconceptions about 'preferred' habitats may lead to biased conclusions about distribution.

Our stratified quasi-random method was applied without prejudging the preferred habitat of ginseng and goldenseal, with two exceptions: (1) we sampled only forested habitats, making the assumption that neither species would be found in open fields or wetlands, and (2) we avoided thick stands of *Rhododendron maximum*, which are known throughout the region to suppress understory herb growth (Van der Voort 1998). Using this sampling approach, we were able to draw conclusions about ginseng distribution that in fact contradict folklore and some previous scientific publications. Prior to our study, the conventional wisdom was that ginseng is found primarily in north-facing 'cove' forests, at least in our sampling universe of the central Appalachian region. With our sampling scheme, however, we showed that east-facing slopes (at mid elevations) and west-facing slopes (at low elevations) were preferred. Moreover, ginseng was occasionally present even on relatively dry south-facing slopes. The lack of differences in ginseng density among four contrasting forest community types also contradicts prior thinking.

The distribution and abundance of ginseng is likely to reflect several confounding factors, both natural and anthropological. For example, following conventional wisdom, harvesters may concentrate their activities in north-facing 'cove' forests, such that fewer plants than expected are now found there. Not suspecting that ginseng has a wider distribution, perhaps harvesters search for ginseng less often on other aspects or forest types. This potential for a direct influence of harvesters on distribution may make it impossible to know the species' natural responses to environmental gradients by describing the status quo. We have learned from our sampling that ginseng is more broadly distributed than previously thought, however. Perhaps south-facing, oak-dominated forests are 'suboptimal' for proliferation of ginseng populations, but they act as refugia from harvesters.

The extrapolation of local ginseng density to the broad area of the entire state of West Virginia is fraught with assumptions, the violation of which could alter both the 87.8 million total plant number and the 4.9% harvest rate estimates. The true total number could be lower than this if we oversampled 'good' ginseng habitat. This oversampling could have occurred by chance or by an unconscious site-selection process. Alternatively, the true number could have been higher than this if we missed plants in the sampling despite our careful surveying because of crypticity or deer browsing, or if our survey inadvertantly undersampled good ginseng habitat. The low sampling rate of private land, for example, could lead to an underestimate of the true natural density for the region. Therefore, this number is best thought of as a first approximation. Prior to this study, however, the only indicator of wide area numbers of what is thought to be a relatively rare plant was the annual harvest. Our data show clearly that ginseng is not rare in the typical sense of low overall numbers. Nevertheless, our sampling also illustrates that ginseng is never abundant. The largest number of plants we ever found in one of our 15 × 400 m transects was 57, but all of these were one-leafed seedlings that had apparently been cached by a small mammal and germinated in a confined area. Most often, densities were much lower than this or zero.

Ginseng is best described as a widespread but scarce understory plant. This is exactly the kind of distribution expected for a plant with a broad niche which has been harvested heavily, particularly in areas where it was formerly abundant. This distribution has important implications for management of the species. As a CITES Appendix II listed species, the federal government must certify that continued harvest is nondetrimental to natural populations. For a widespread but scarce plant, making such a determination requires monitoring of populations over a broad area. Harvest totals do not serve as a measure of population size since a complex of factors from employment rates to drought can affect annual harvest (Bailey 1999). Individual plant size is also only a weak indicator of the health of natural populations since plant size changes over time may have little to do with age (McGraw 2001). Implementation of a standardized monitoring protocol would further make the data useful for population biologists, so projections of population fates could be made in advance of a major calamity requiring complete closure of the ginseng trade.

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